

# TES and sonde O3 profile comparisons

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TES Team

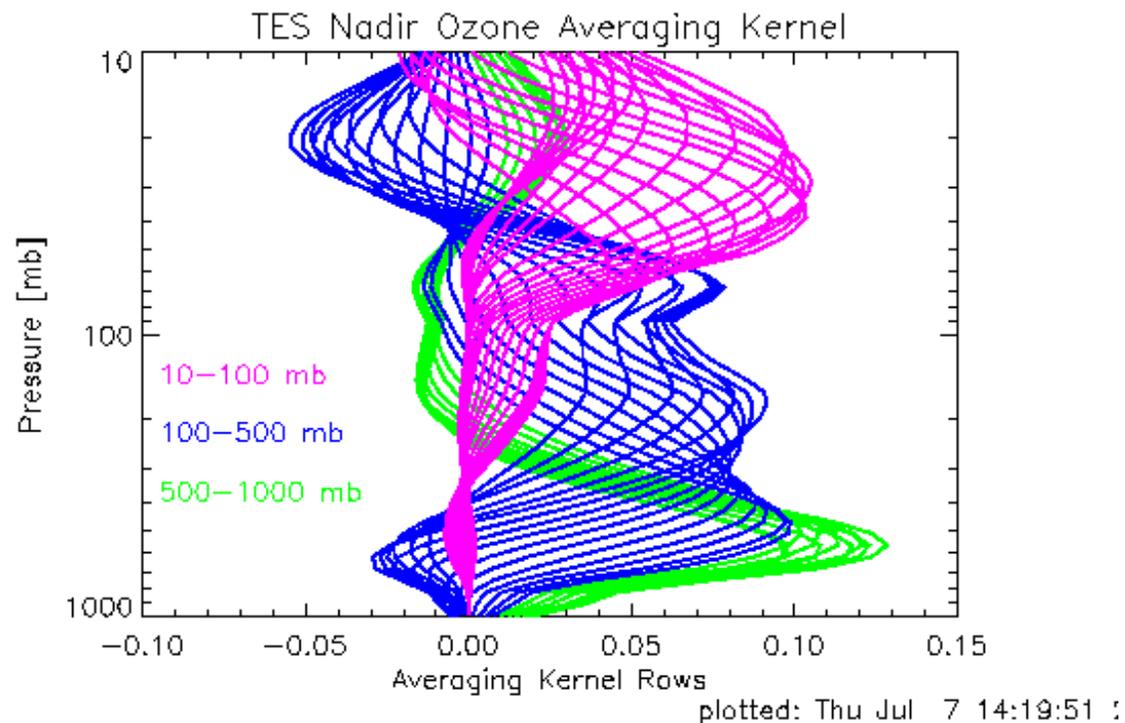
# PROCEDURE FOR COMPARISONS

1. Map O3 sonde profile to TES 87 pressure levels grid:

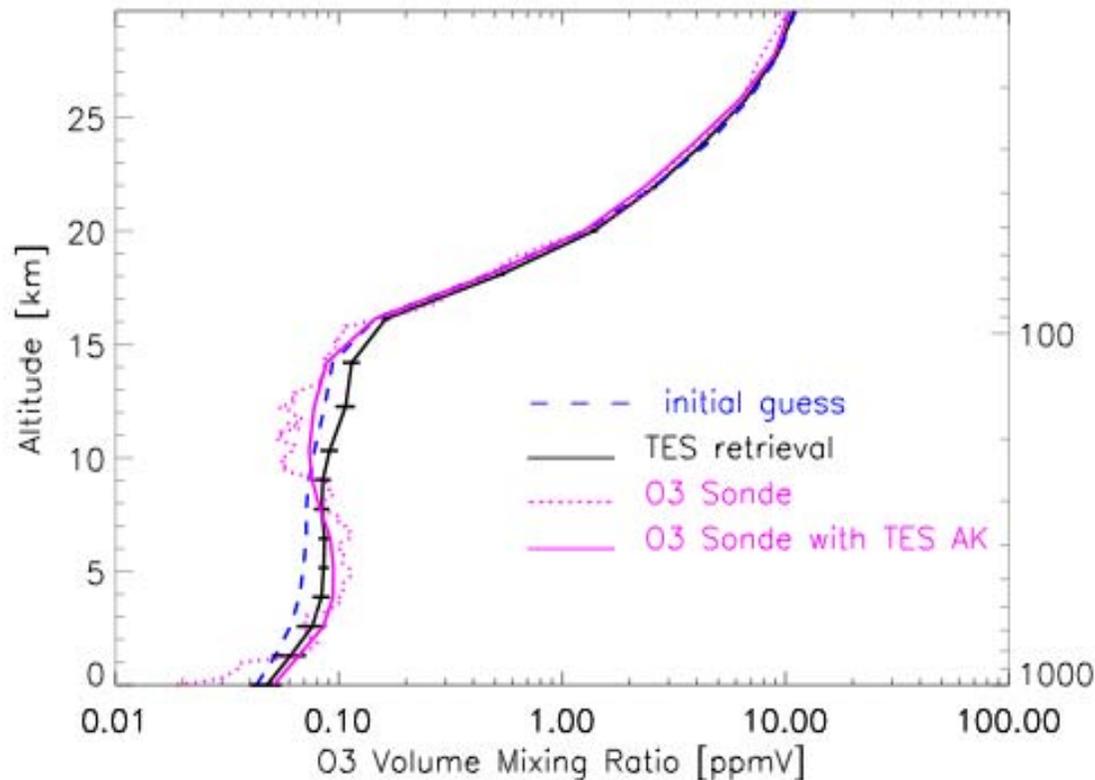
$$\mathbf{x}_{sonde}^{pTES} = \mathbf{M}_{pTES \Rightarrow P_{sonde}}^{-1} \mathbf{x}_{sonde}$$

2. Apply averaging kernel,  $A_{TES}$ , and a *a priori* constraint:

$$\mathbf{x}_{sonde}^{TES_{AK}} = \mathbf{x}_{apriori} + \mathbf{A}_{TES} [\mathbf{x}_{sonde}^{pTES} - \mathbf{x}_{apriori}]$$



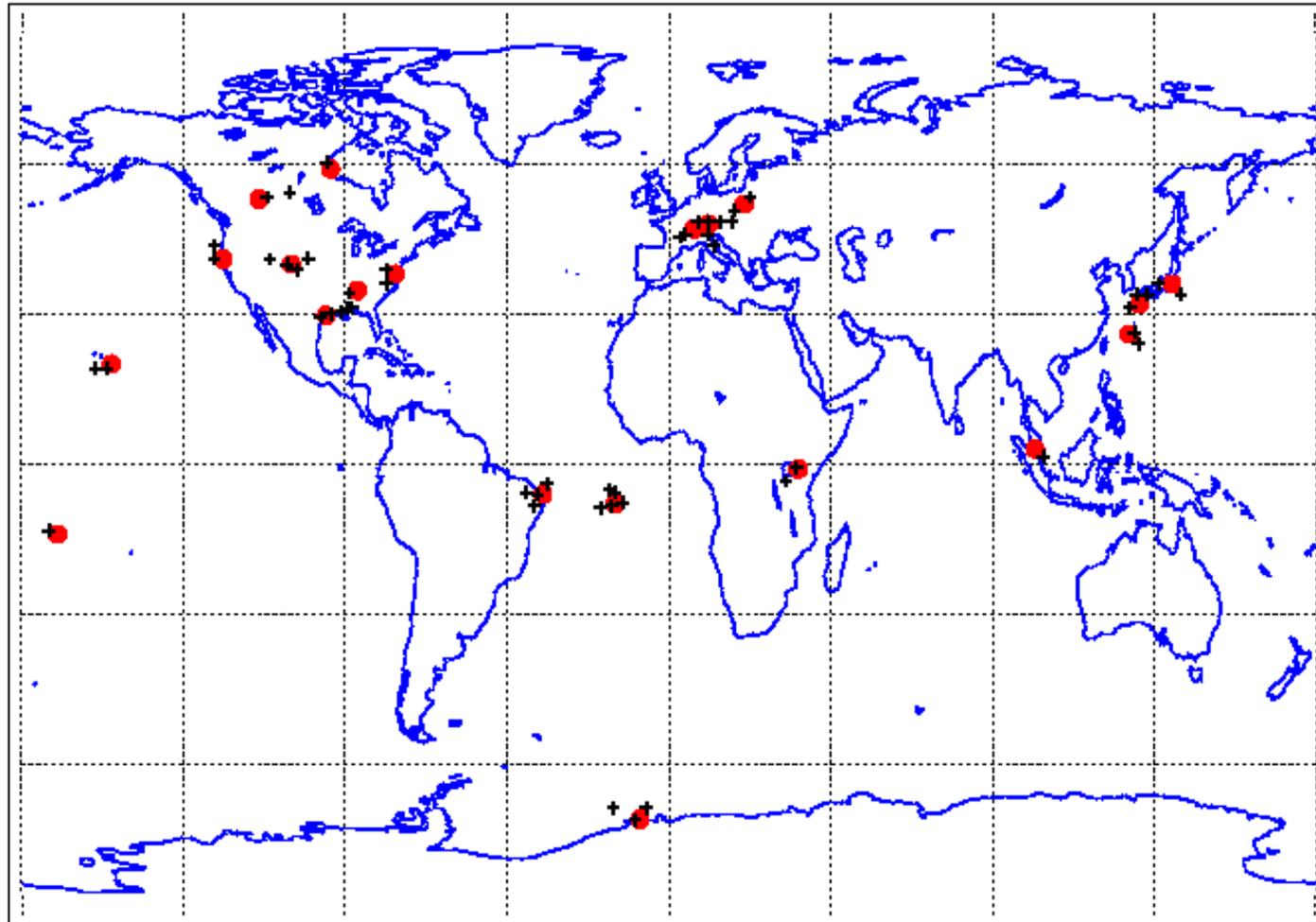
## 3. Compare to TES profile using retrieval error terms: Measurement Error + Cross-State Errors



O<sub>3</sub> Sonde from Ascension Island  
7.95°S, 14.37°W  
Launched 10/11/2004, 13:50 UTC  
Closest TES nadir measurement  
(Step/Stare run 2199):  
7.756°S, 12.934°W  
(160 km away)

DOFS: 3.7  
Vertical res: 6 to 9 km  
(avg = 7.2 km)  
in troposphere < 200 mb

# Fall 2004 TES-ozonesonde data coincidences



+ indicates TES nadir measurement

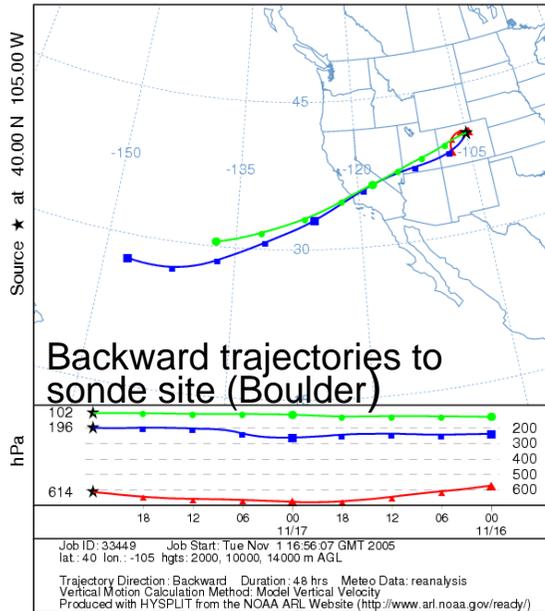
SHADOZ, WOUDC data via Harvard and dedicated AVE launches (Houston)

# Sonde/Nadir Measurement Coincidence Criteria

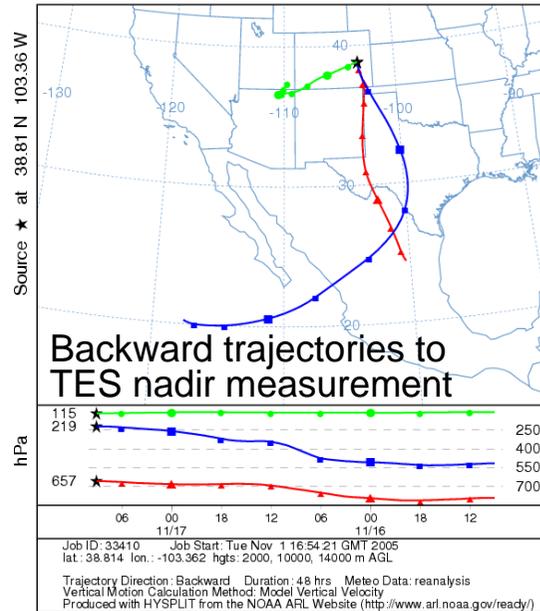
- Applied for fall 2004 (9/20 - 11/17) TES data both global survey & step/stare runs
- SHADOZ & WOUDC data via Harvard + dedicated AVE launches (Houston)
  
- Initial: 600 km, 48 hours (800 km for AVE),  $\text{Chi}^2 < 2$   
=> 55 coincidences
  
- More selective: Sonde-TES  $T_{\text{diff}} < 5\text{K}$ ,  $\text{lat} < 55^\circ$   
=> 44 coincidences

# Trajectories for 11/17/2004, Boulder

NOAA HYSPLIT MODEL  
Backward trajectories ending at 00 UTC 18 Nov 04  
CDC1 Meteorological Data



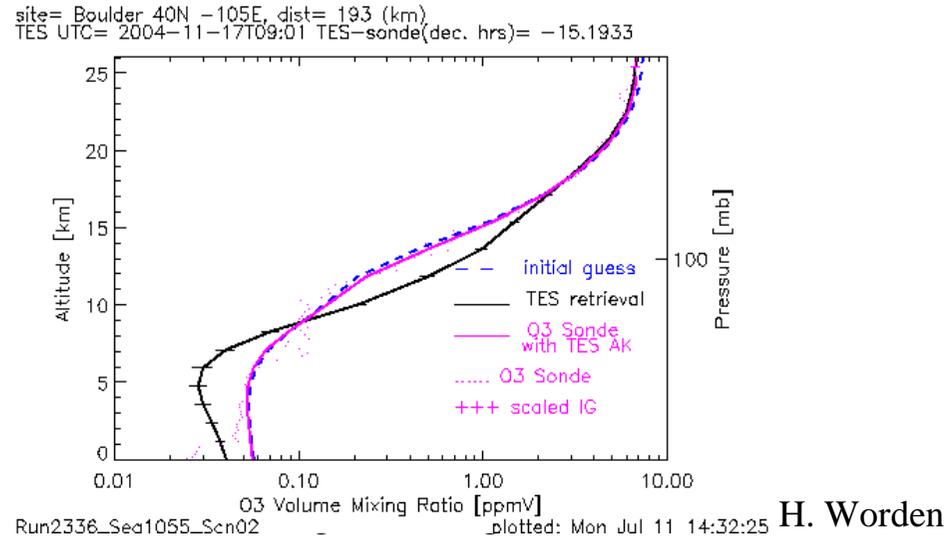
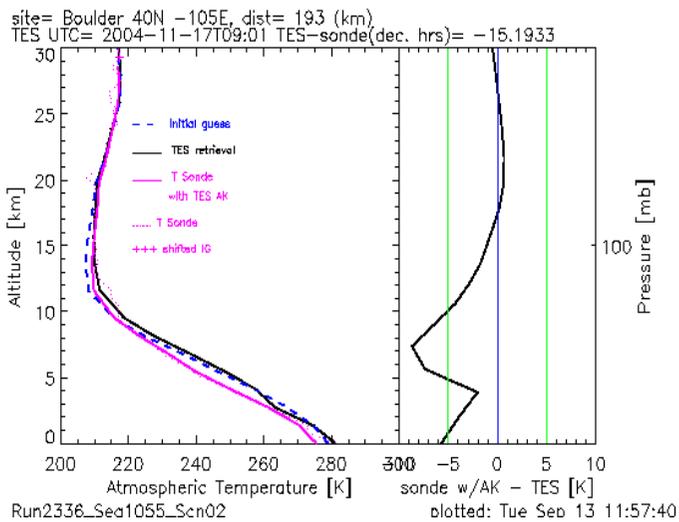
NOAA HYSPLIT MODEL  
Backward trajectories ending at 09 UTC 17 Nov 04  
CDC1 Meteorological Data

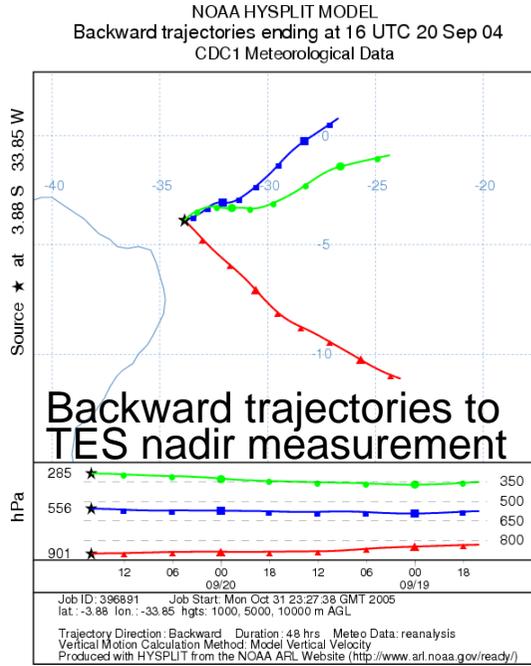
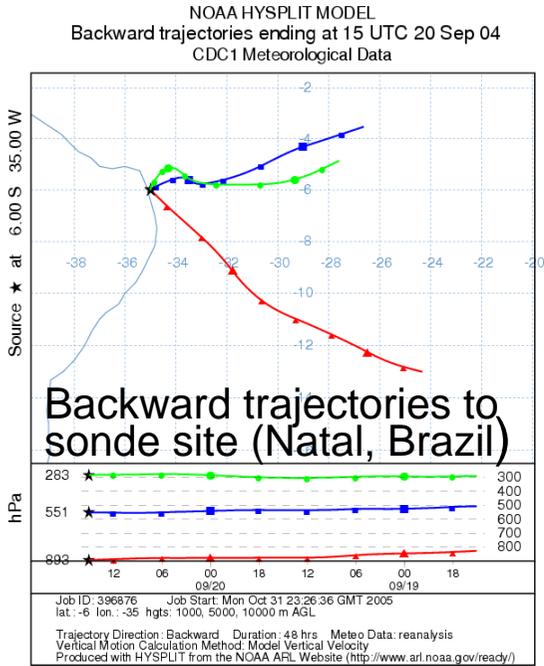


Dist |Sonde-TES|:  
193 km

Time difference:  
15 hrs

## Sonde vs. TES: Temperature and Ozone



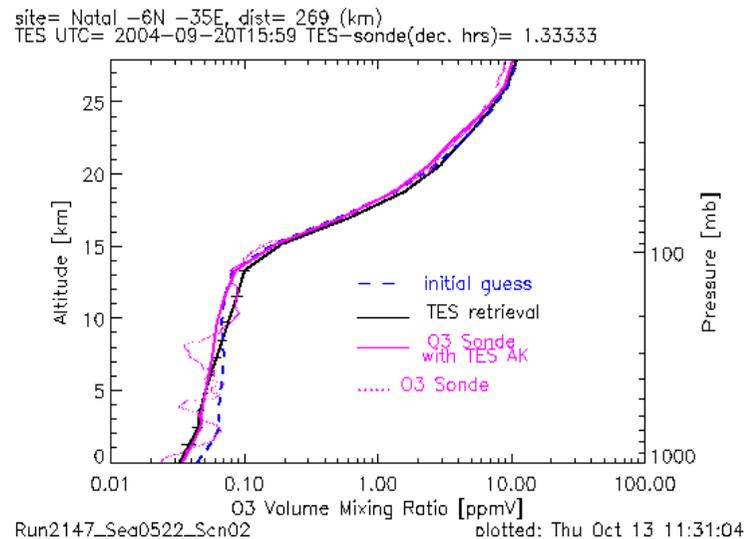
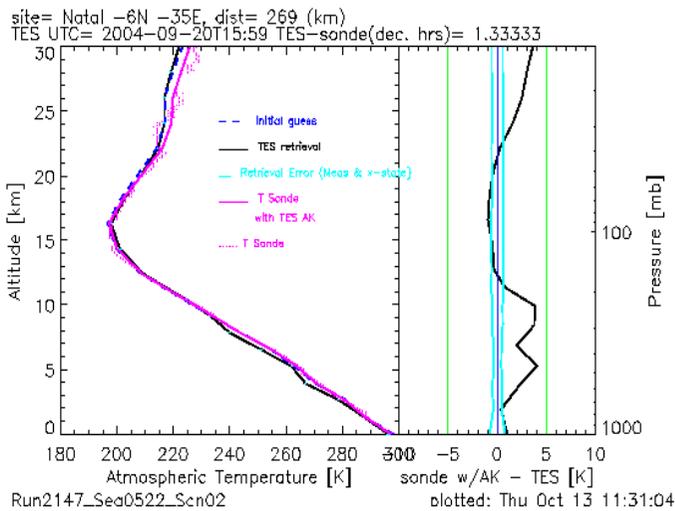


Time difference:  
1 hr

## Sonde vs. TES: Temperature

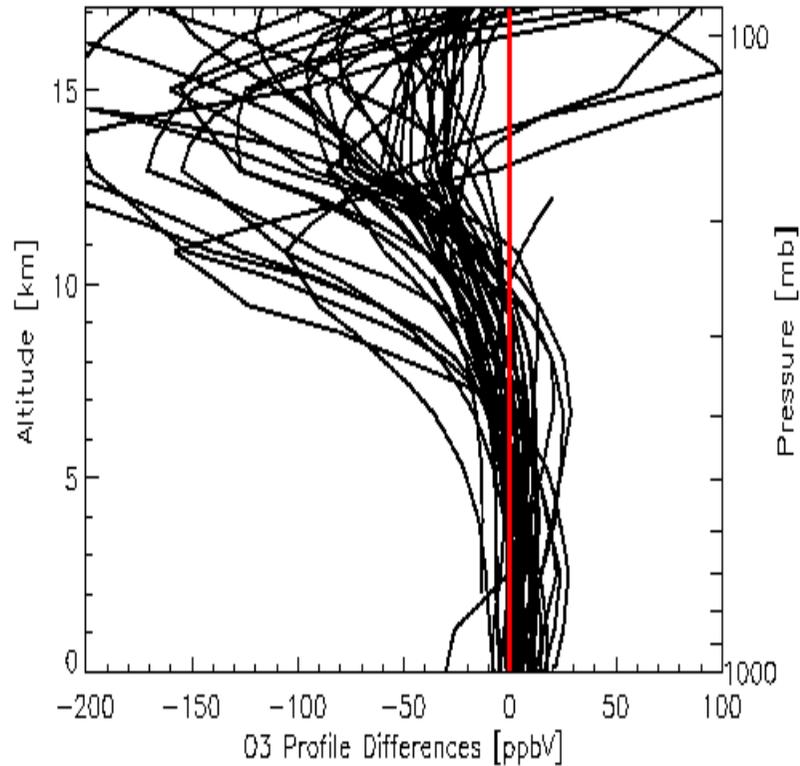
and

## Ozone

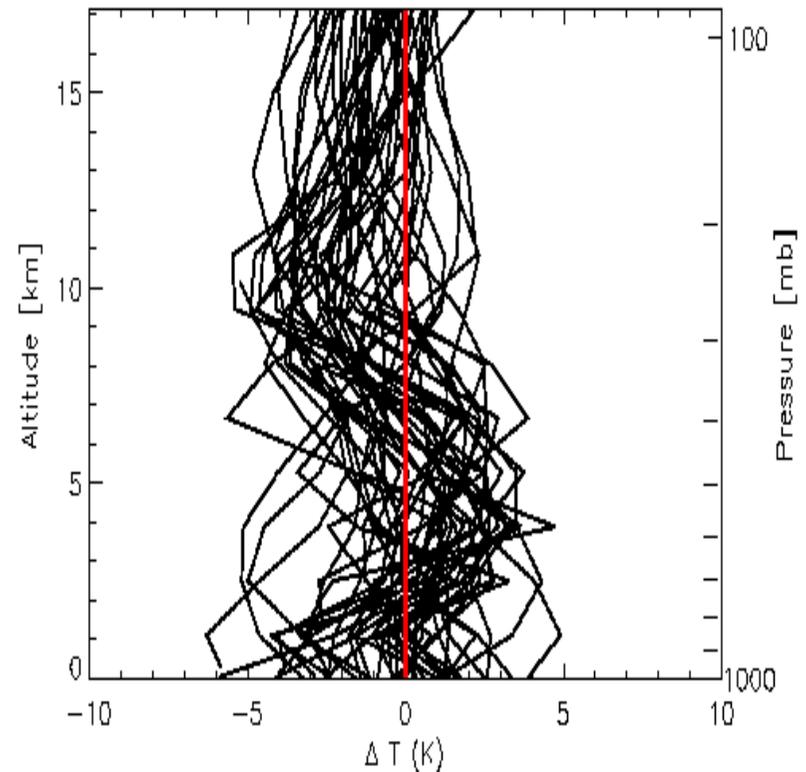


# Sonde (w/TES AK) - TES comparisons: Ozone and Temperature profiles

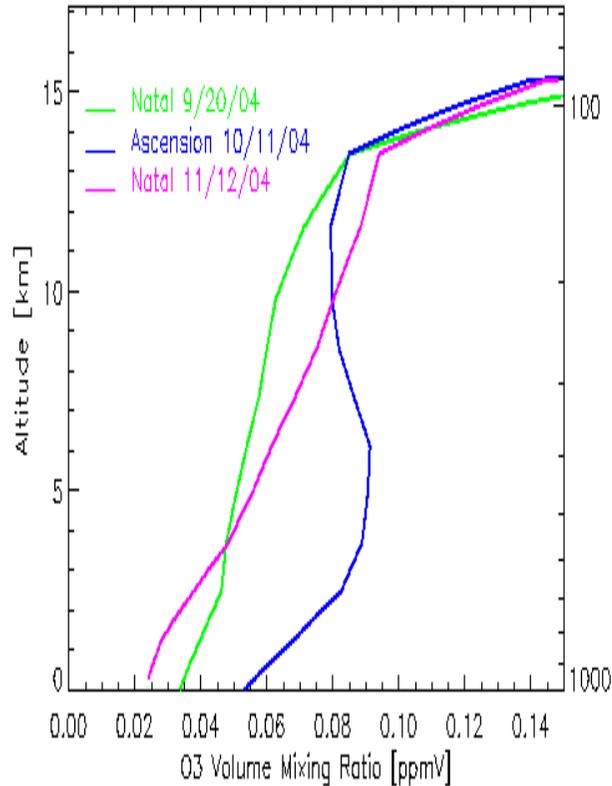
Tropospheric Profile Differences [Sonde(w/TES AK) - TES],  
Fall 2004 comparisons



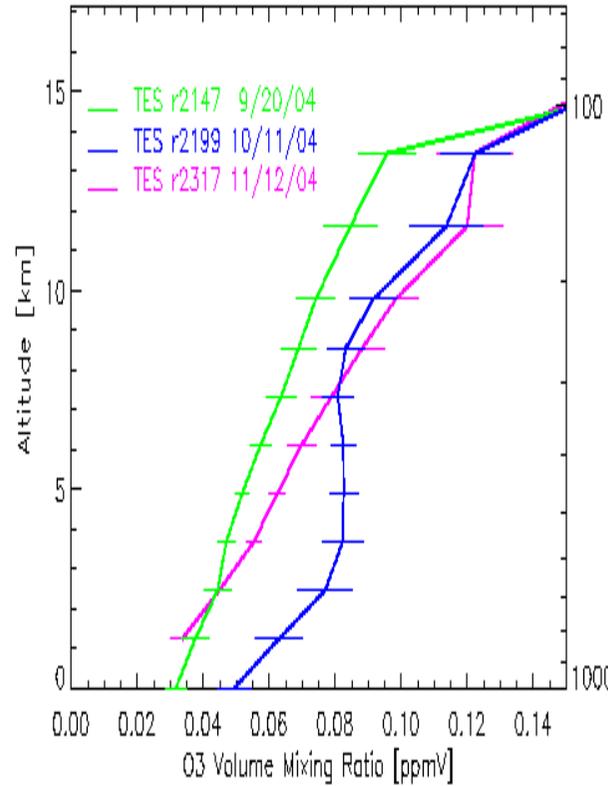
Atmospheric Temperature Differences [Sonde(w/TES AK) - TES],  
Fall 2004 comparisons



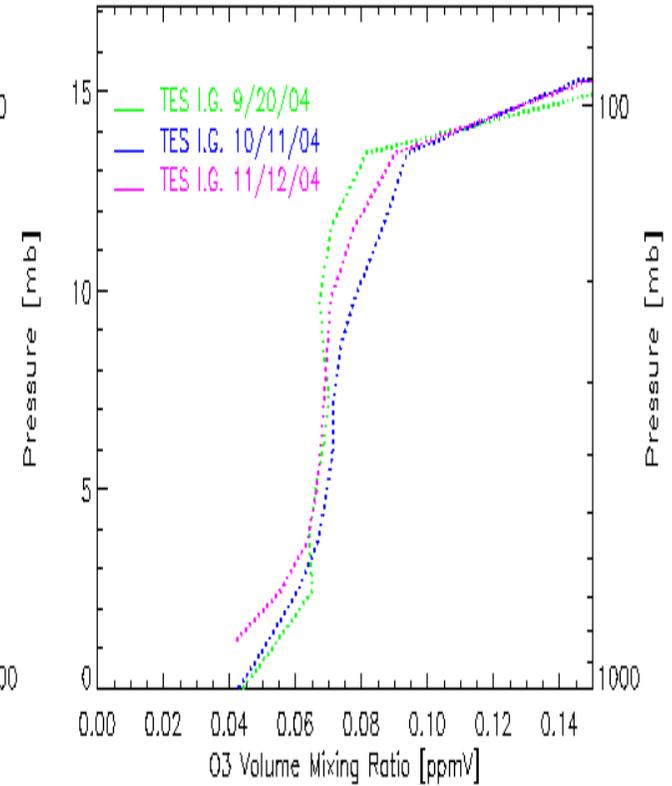
# Comparison of 3 sonde profiles (with TES AK) and 3 TES retrieved profiles - tropics



sonde

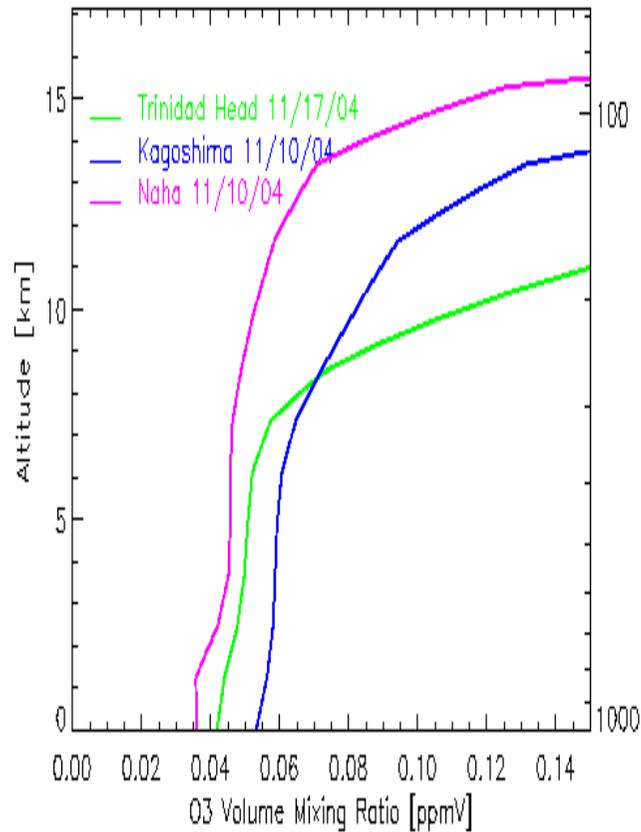


TES retrieval

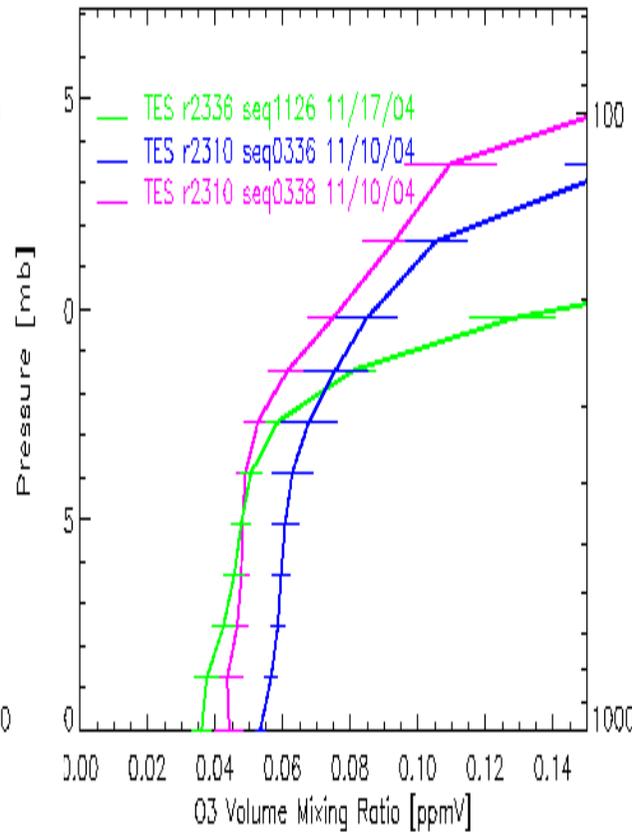


initial guess

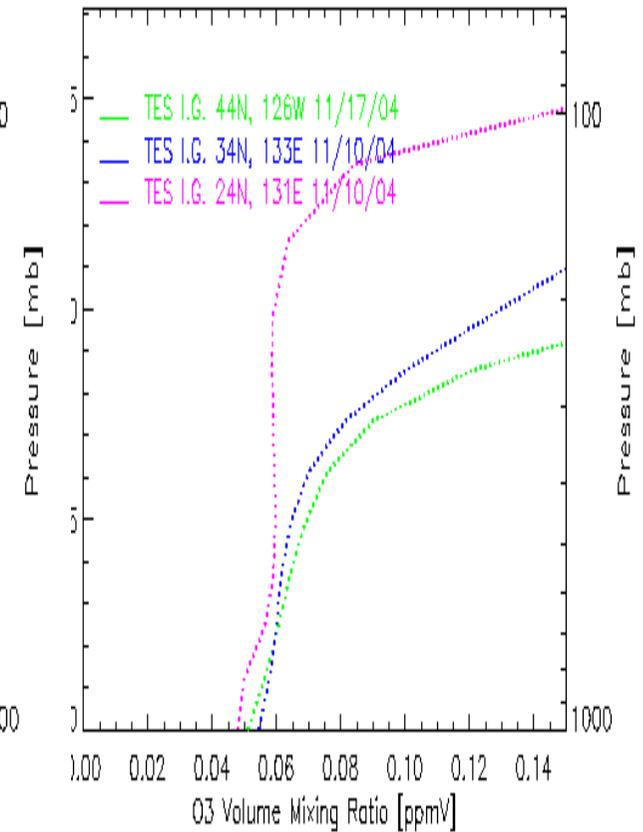
# Comparison of 3 sonde profiles (with TES AK) and 3 TES retrieved profiles - sub-tropics/mid-latitude



sonde



TES retrieval



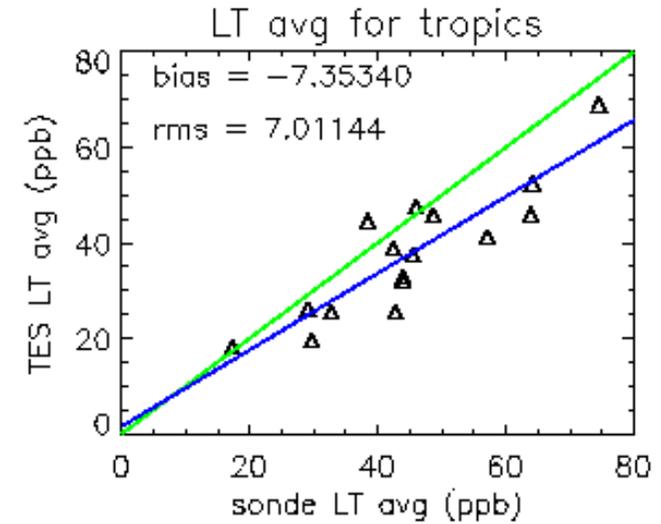
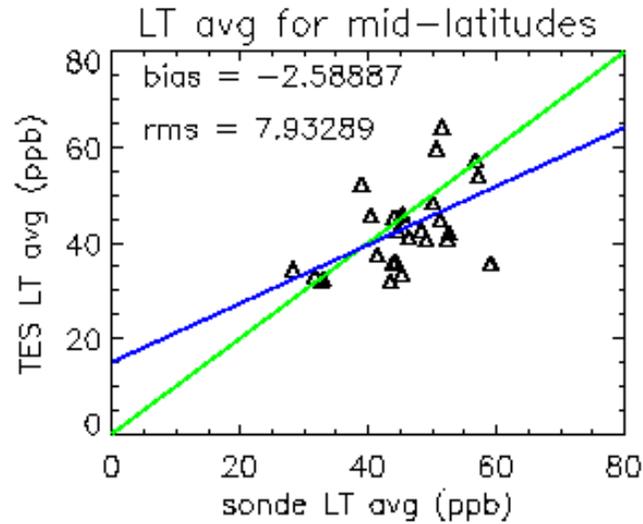
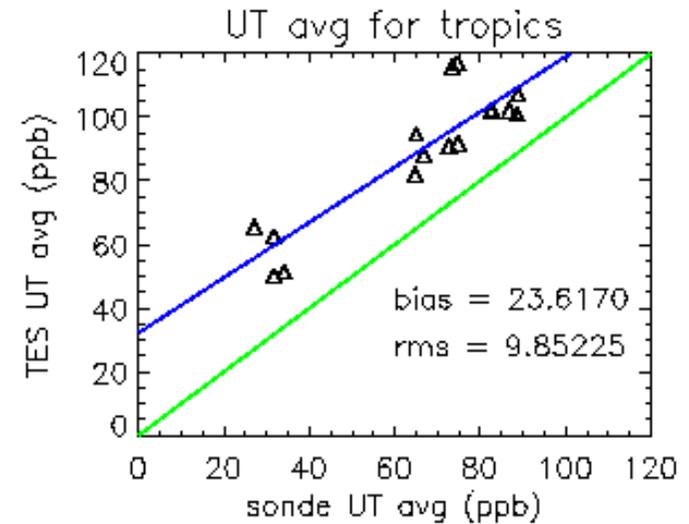
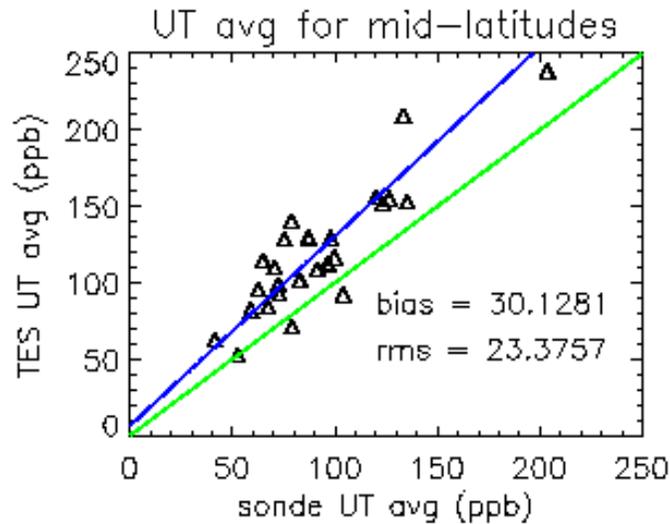
initial guess

# TES vs. sonde O3 averages for mid-lat & tropics

Upper Trop  
(UT)  
500mb > p > p<sub>TP</sub>

— 1 to 1

Lower Trop  
(LT)  
p > 500mb

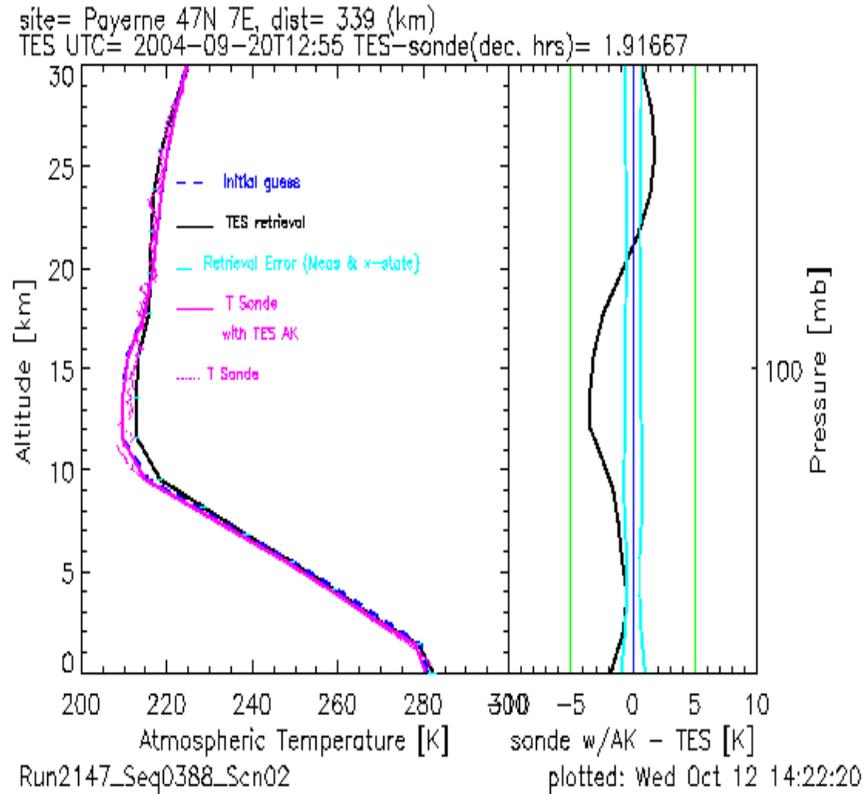


28 coincidences

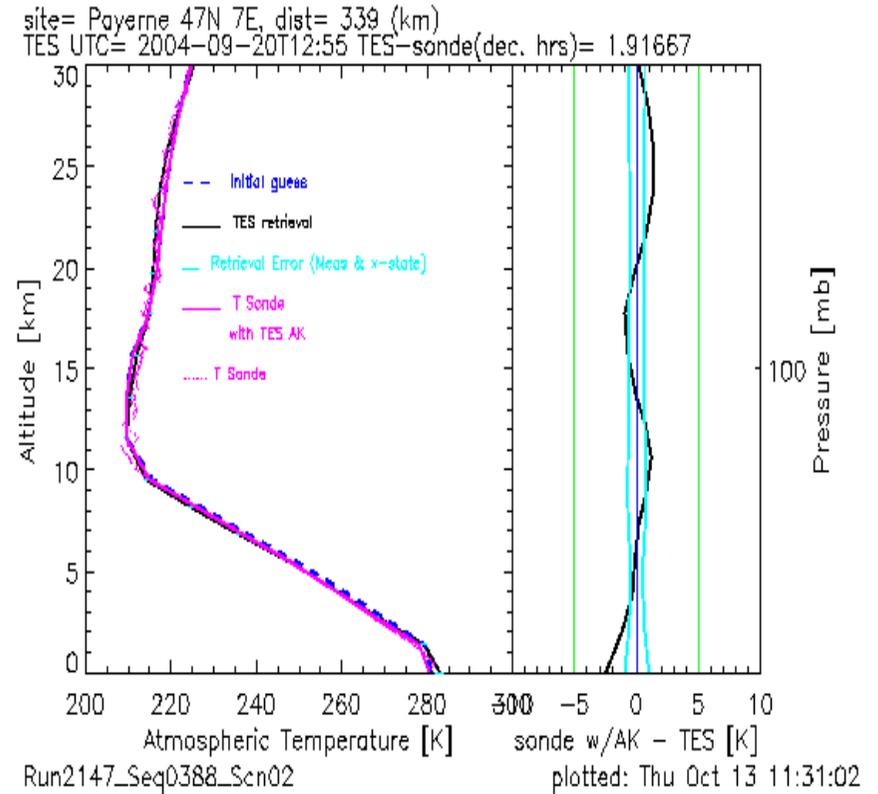
16 coincidences

- We have also looked at UT & LT differences vs:
  - distance to sonde site (km)
  - $\Delta$ time (hrs)
  - retrieval  $\chi^2$
  - retrieved cloud top pressure
  - avg. sonde vmr
- Hard to see any definite trends...
- Next: improved L1B calibration
  - >1K difference with AIRS is now <0.5 K  
(see TES Radiometric Assessment poster)

# Temperature profiles (sonde vs. TES)



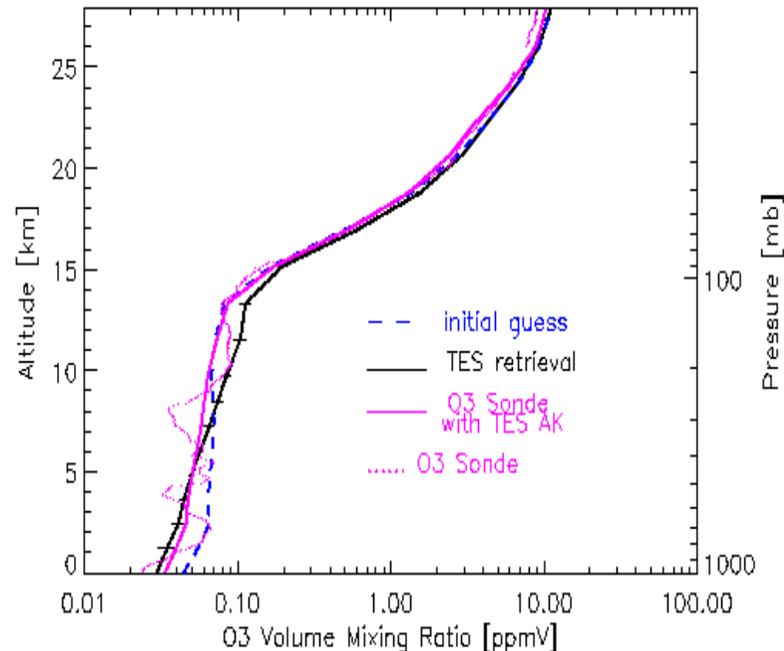
comparison  
with current L1B



comparison with  
L1B calfit prototype

Payerne (47° N, 7° E)

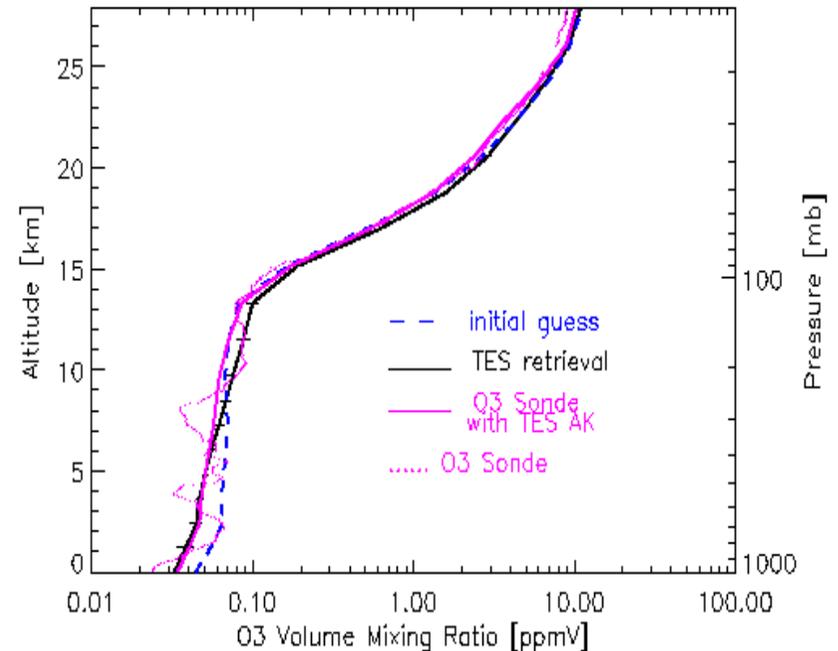
site= Natal -6N -35E, dist= 269 (km)  
TES UTC= 2004-09-20T15:59 TES-sonde(dec. hrs)= 1.33333



Run2147\_Seq0522\_Scn02

plotted: Mon Jul 11 14:18:11

site= Natal -6N -35E, dist= 269 (km)  
TES UTC= 2004-09-20T15:59 TES-sonde(dec. hrs)= 1.33333



Run2147\_Seq0522\_Scn02

plotted: Thu Oct 13 11:31:04

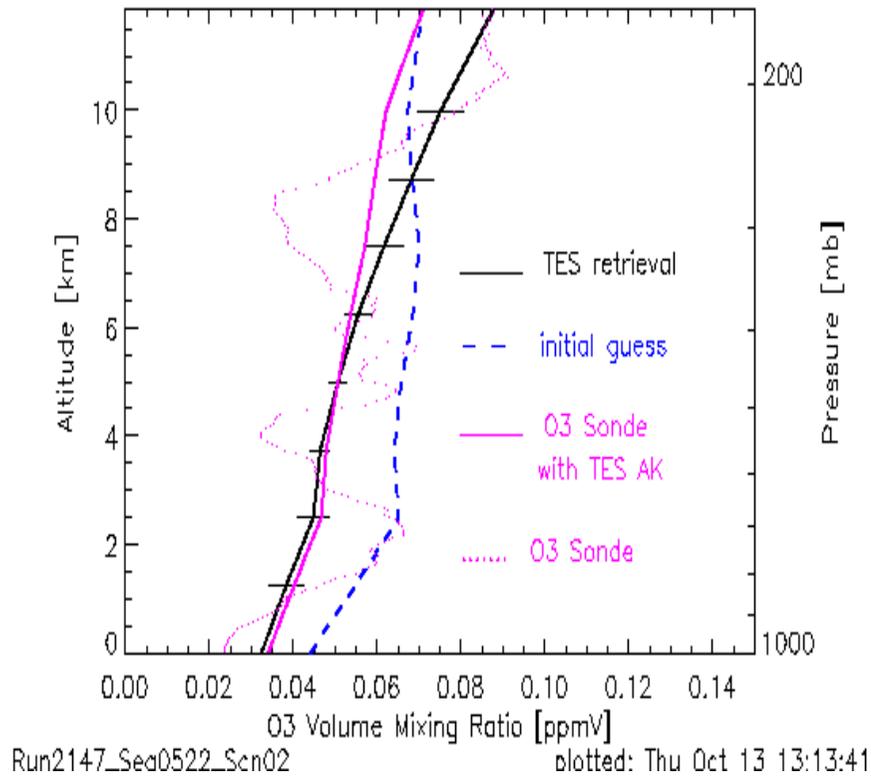
## Sonde comparison with current L1B

## L1B calfit prototype comparison

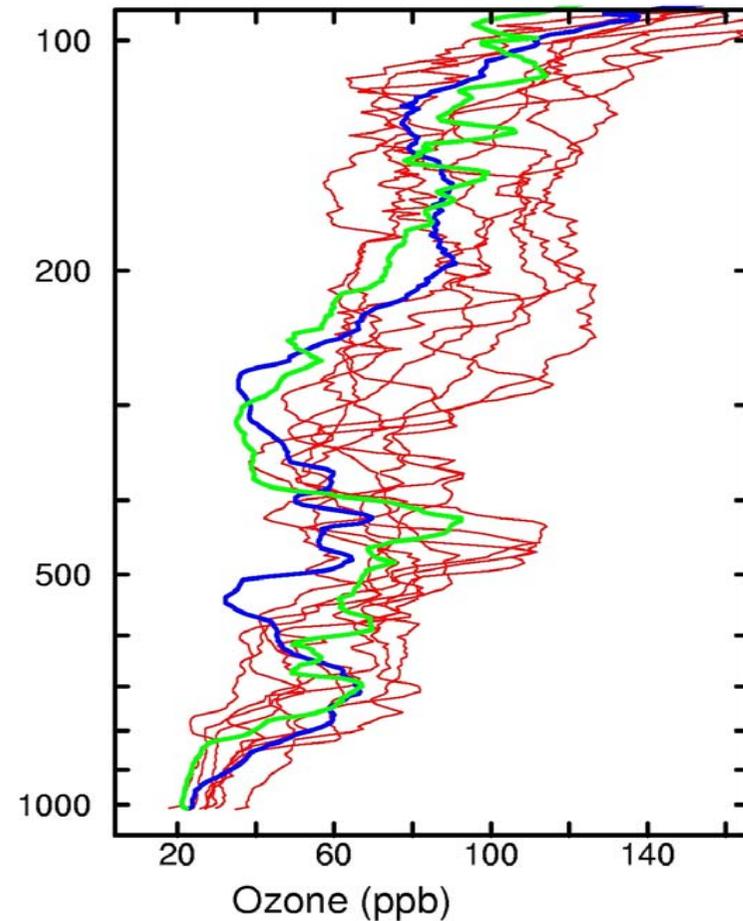
Natal, Brazil (6° S, 35° W)

Note improvement is mainly in the upper trop. as expected  
since lower radiances had the largest correction.

site= Natal -6N -35E, dist= 269 (km)  
 TES UTC= 2004-09-20T15:59 TES-sonde(dec. hrs)= 1.33333



L1B calfit prototype comparison  
 (troposphere, linear scale)

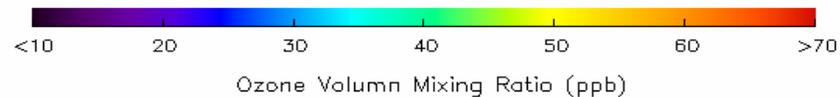
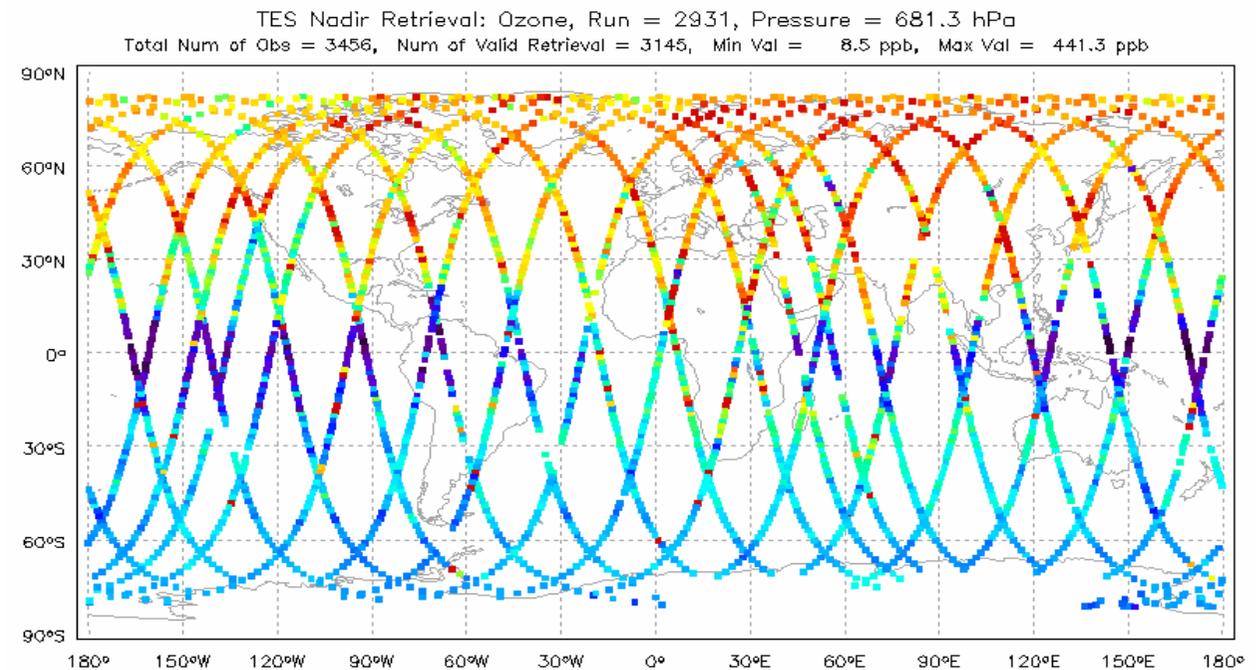
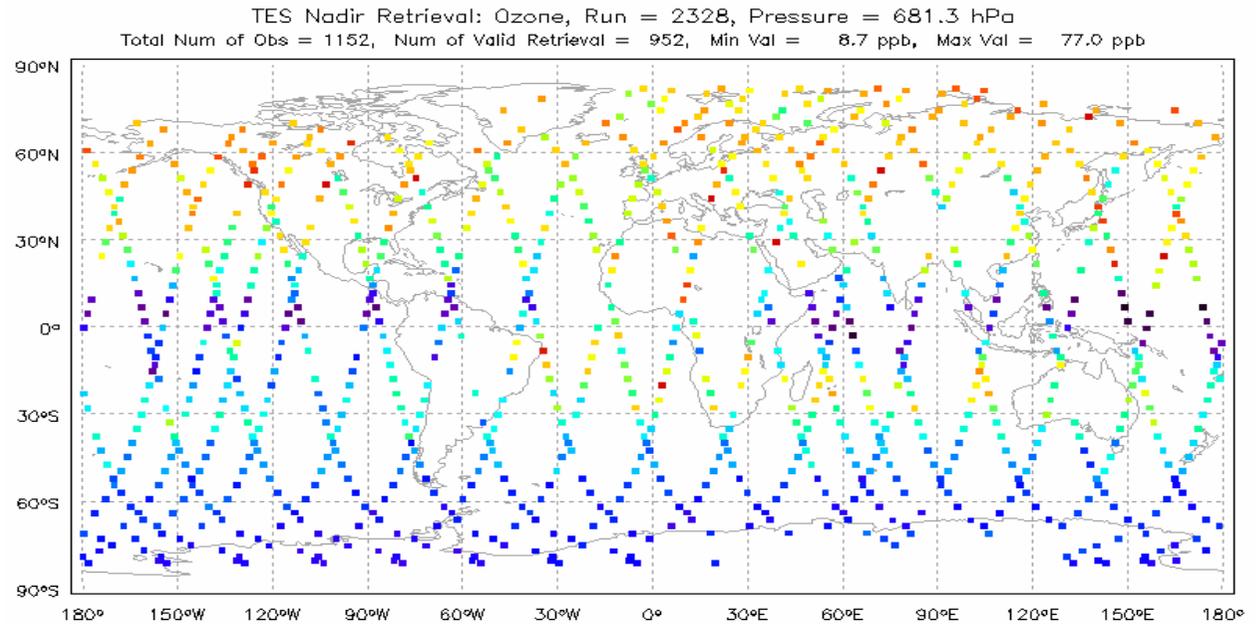


Natal O3 sonde data for  
 for Sep/Oct 2004



TES Global Survey  
with 2 nadir, 3 limb  
scans/sequence.  
Nadir scans are  
averaged (3 limb  
scans not shown)  
14-15 Nov. 2004

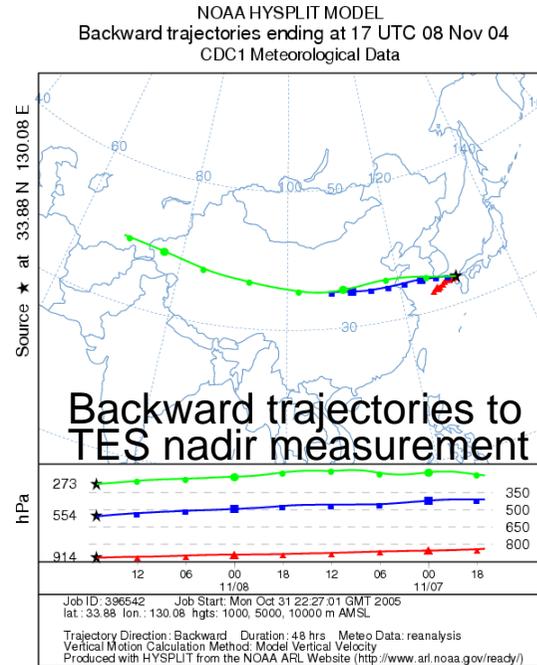
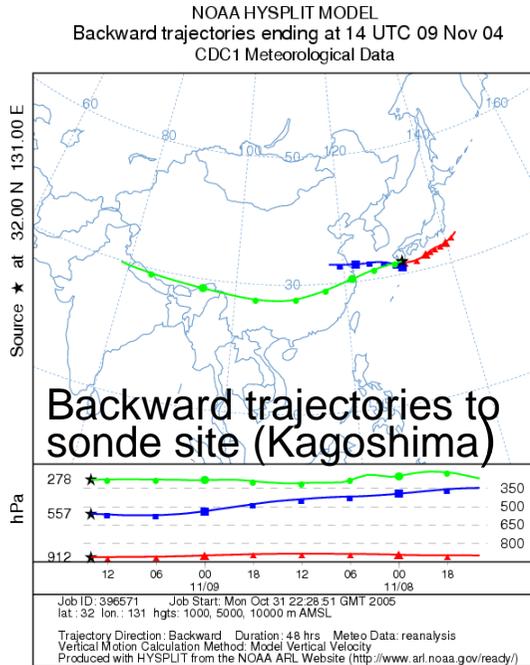
TES Global Survey  
with 3 nadir scans/  
sequence. Nadir  
scans are not  
averaged. No limb  
scans taken.  
21-22 May 2005



## Conclusions

- Comparisons to O3 sondes for current TES (v1, beta quality) data available at DAAC show:
  - TES is able to detect expected variability in the lower troposphere.
  - Bias in the upper troposphere is:
    - latitude dependent
    - peaked at 200 - 150 hPa
  
- Comparisons for data with improved L1B calibration (only 3 cases available) show less bias in the upper troposphere.
  
- Coincidence criteria are tricky for tropospheric comparisons but:
  - Cut on TES-sonde tropospheric temperature differences seems to be a pretty good proxy for trajectory analysis.
  - Will have more matches with denser nadir coverage (started in May 2005)

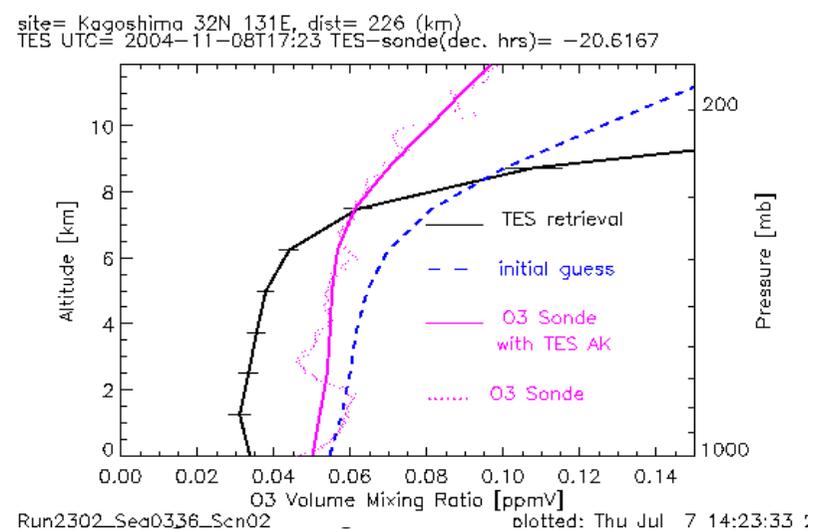
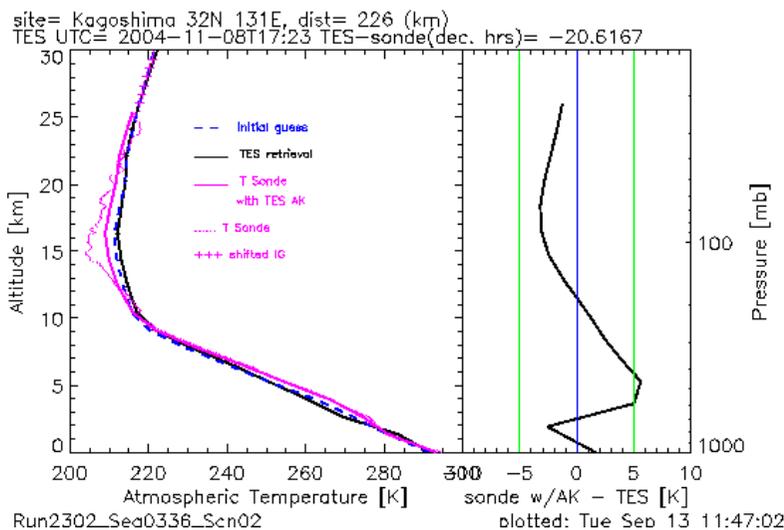
# Backup Slides



Dist |Sonde-TES|:  
226 km

Time difference:  
21 hrs

## Sonde vs. TES: Temperature and Ozone

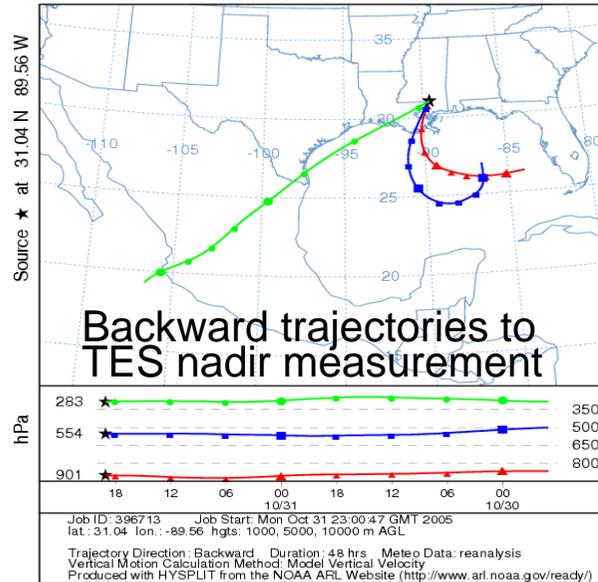


# Trajectories for 10/31/2004 (AVE)

NOAA HYSPLIT MODEL  
Backward trajectories ending at 18 UTC 31 Oct 04  
CDC1 Meteorological Data



NOAA HYSPLIT MODEL  
Backward trajectories ending at 19 UTC 31 Oct 04  
CDC1 Meteorological Data



Dist |Sonde-TES|:  
580 km

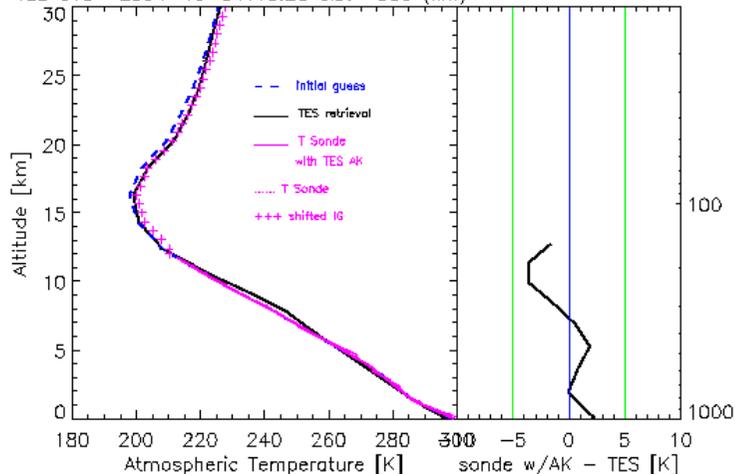
Time difference:  
1hr

## Sonde vs. TES: Temperature

and

## Ozone

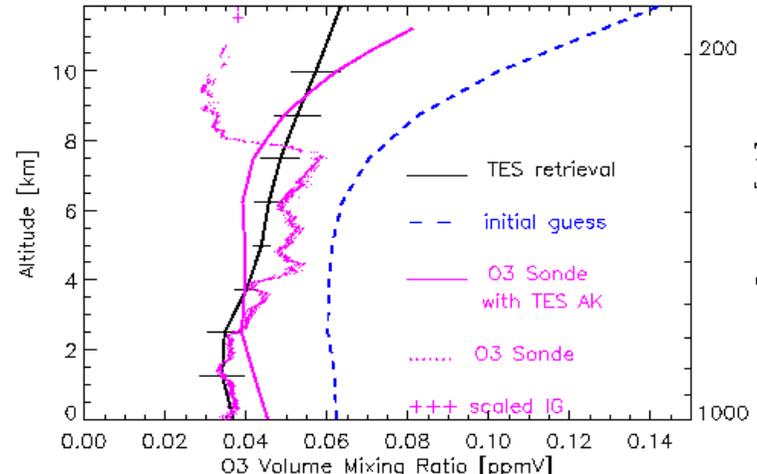
site= Houston/AVE, file= /project/lt\_ref0/sonde/houston/RU20041031\_1810.(  
TES UTC= 2004-10-31T19:20 dist= 580 (km)



Run2262\_Seq0003\_Scn20

plotted: Tue Sep 13 12:12:26

site= Houston/AVE, file= /project/lt\_ref0/sonde/houston/RU20041031\_1810.(  
TES UTC= 2004-10-31T19:20 dist= 580 (km)



Run2262\_Seq0003\_Scn20

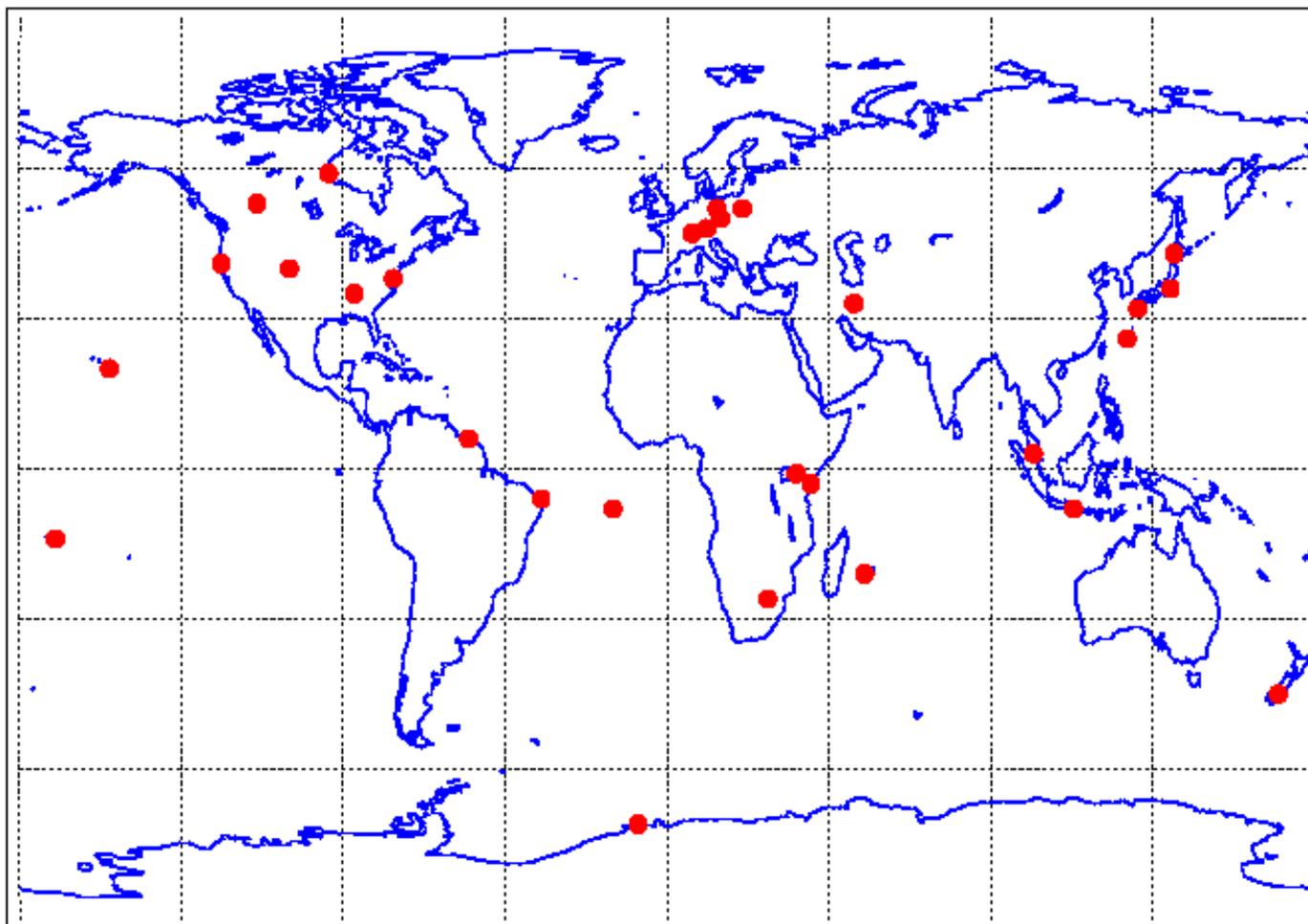
plotted: Thu Jul 7 14:57:15 ;  
/project/lt\_ref0/sonde/houston/RU20041031\_1810.O3SND

# TES Retrieval Error

$$\begin{aligned}
 \mathbf{S}_{\%} = & \quad \text{(Total Error Covariance)} \\
 & (\mathbf{A}_{\text{xx}} - \mathbf{I}) \mathbf{S}_a (\mathbf{A}_{\text{xx}} - \mathbf{I})^T + \quad \text{(Smoothing Error)} \\
 & (\mathbf{A}_{\text{xx}_{\text{CT}}} ) \mathbf{S}_a^{\text{x}_{\text{CT}} \text{x}_{\text{CT}}} (\mathbf{A}_{\text{xx}_{\text{CT}}} )^T + \quad \text{(Cross-Term Error} \\
 & \quad \text{includes T, H2O for joint retrieval with O3)} \\
 & \mathbf{M} \mathbf{G}_z \mathbf{S}_n \mathbf{G}_z^T \mathbf{M}^T + \quad \text{(Measurement Error)} \\
 & \sum_i \mathbf{M} \mathbf{G}_z \mathbf{K}_b^i \mathbf{S}_b^i (\mathbf{M} \mathbf{G}_z \mathbf{K}_b^i )^T \quad \text{(Systematic Errors)}
 \end{aligned}$$

Where  $\mathbf{A}$  is the averaging kernel,  $\mathbf{M}$  is a linear mapping matrix on pressure levels,  $\mathbf{G}$  is the gain matrix and  $\mathbf{K}$  is Jacobian matrix.

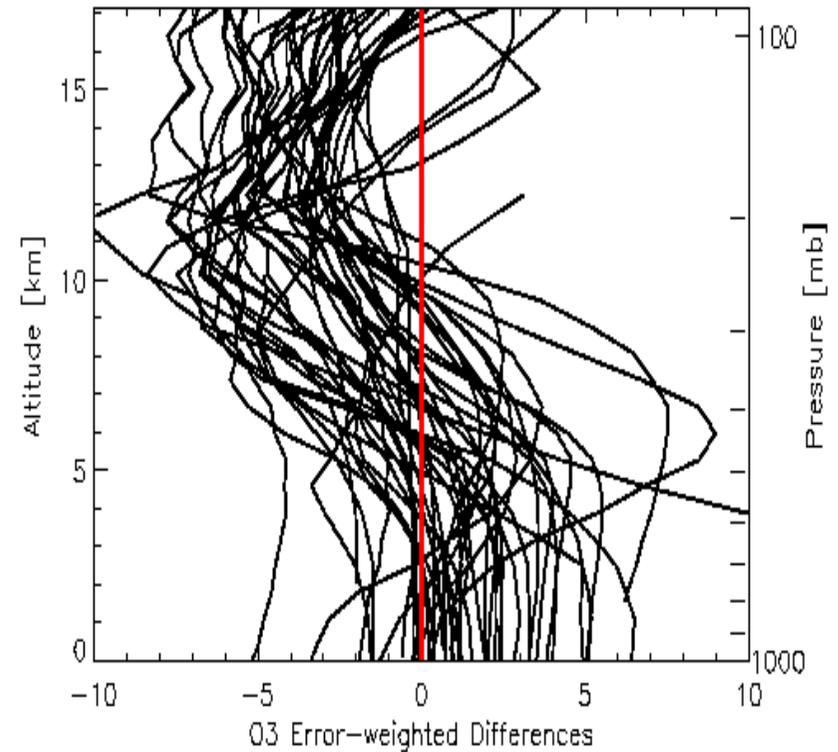
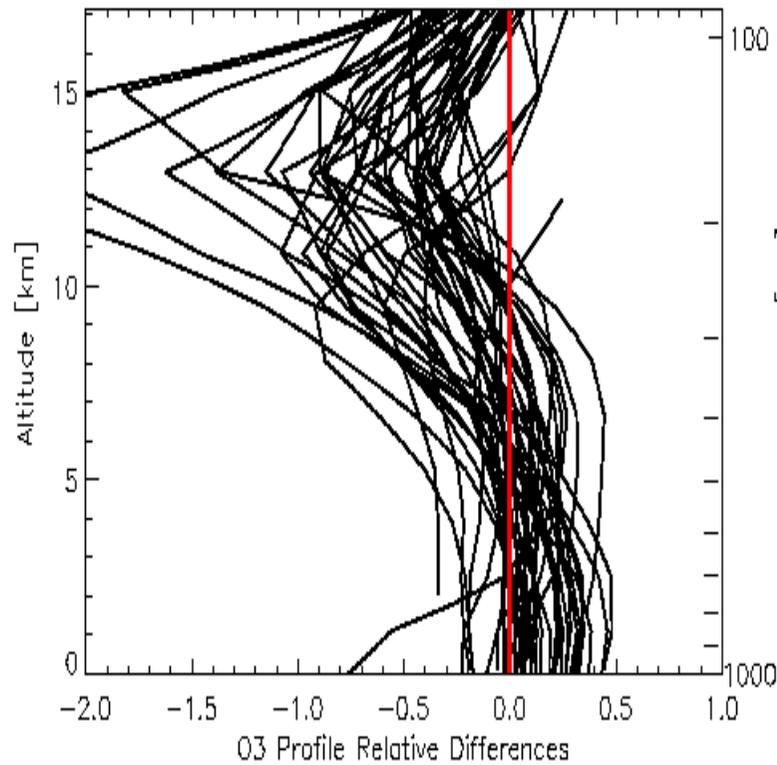
Fall 2004 03 sonde data available from Harvard



# Sonde (w/TES AK) - TES comparisons: O3 relative and error weighted differences

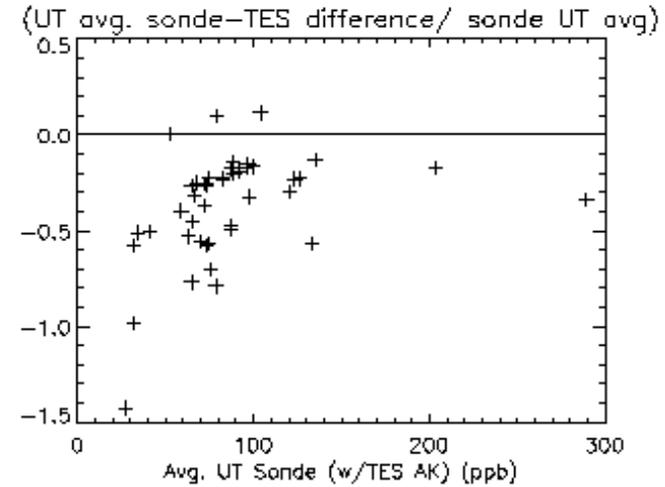
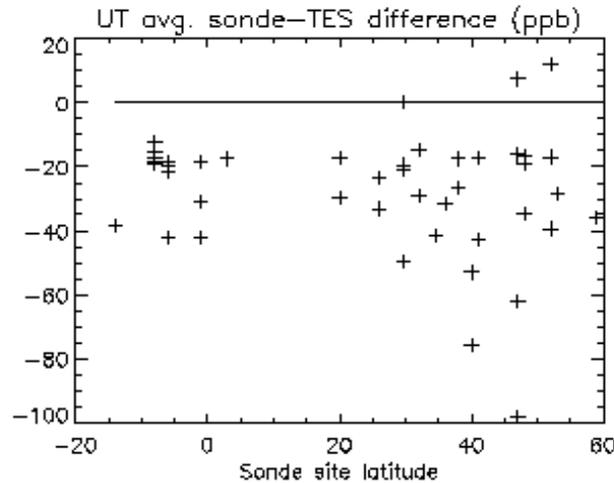
Tropospheric Rel. Differences  $[Sonde(w/TES\ AK) - TES]/Sonde$ ,  
Fall 2004 comparisons

Error Weighted Differences  $[Sonde(w/TES\ AK) - TES]/TES\_err$ ,  
Fall 2004 comparisons

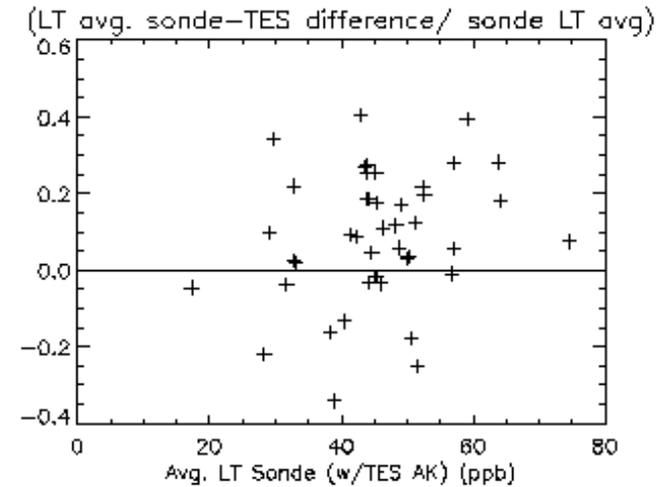
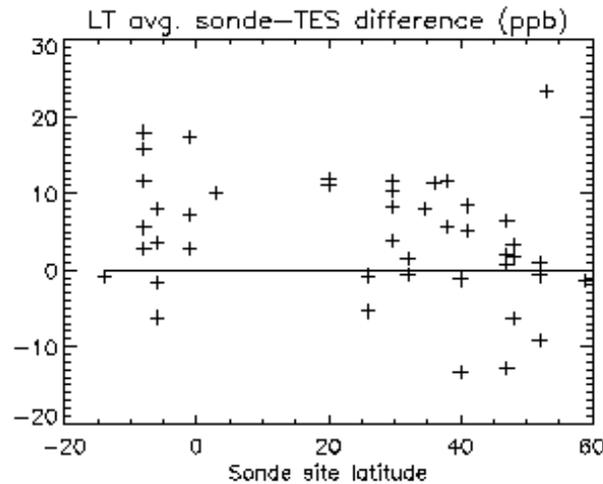


# Differences vs. latitude & sonde O3 vmr averages

Upper  
Trop  
(UT)

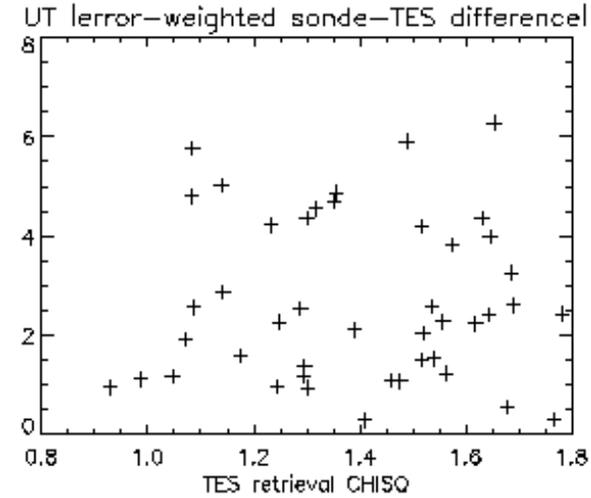
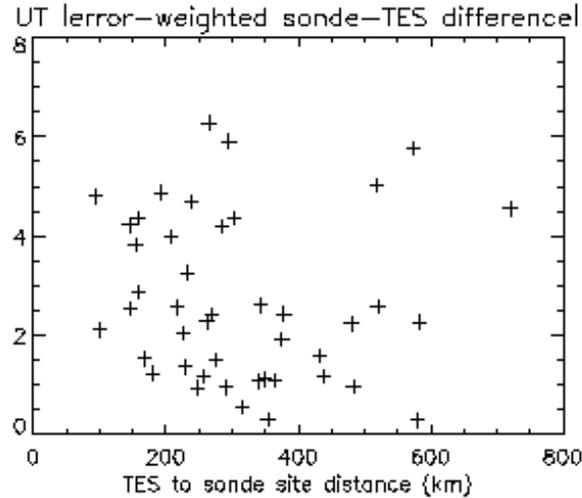


Lower  
Trop  
(LT)

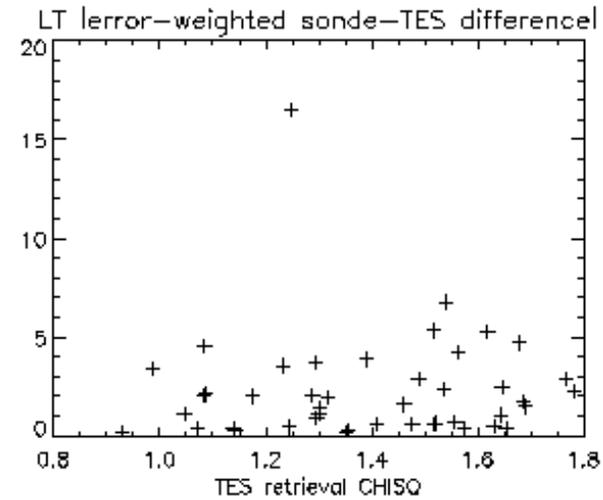
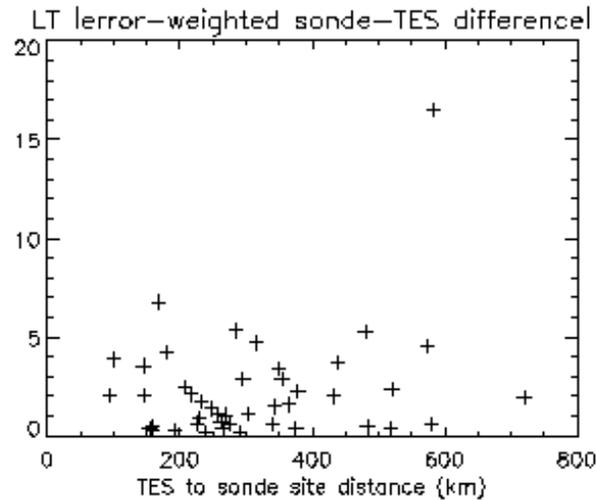


# Error weighted differences vs. distance & retrieval $\chi^2$

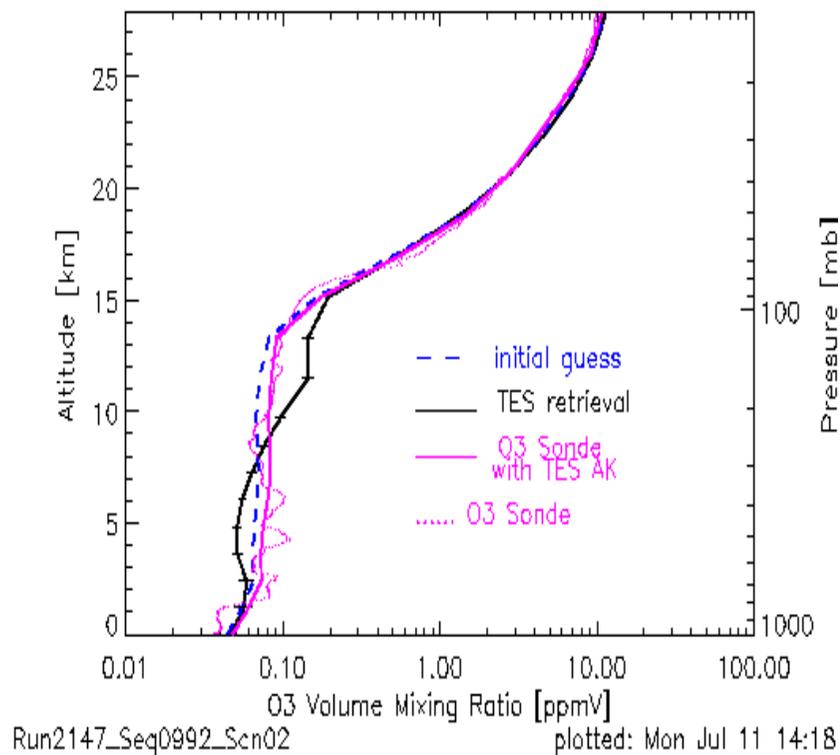
Upper  
Trop  
(UT)



Lower  
Trop  
(LT)



site= Ascension -8N -15E, dist= 354 (km)  
TES UTC= 2004-09-21T02:44 TES-sonde(dec. hrs)= -11.9367



## Sonde comparison with current L1B

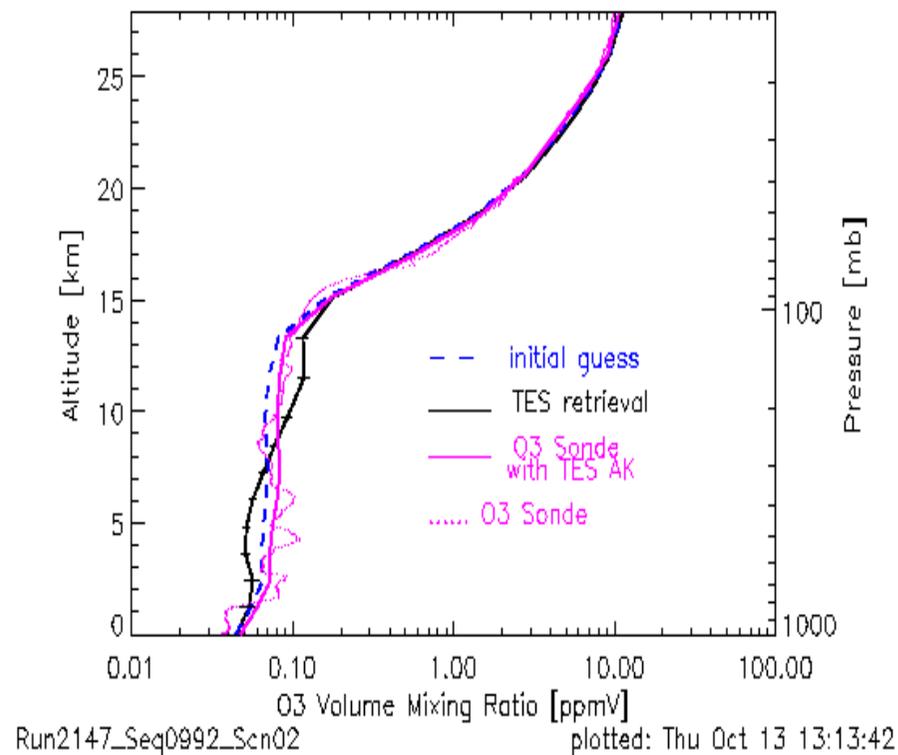
Ascension Is. (8° S, 15° W)

Also slight improvement in upper trop.

November 2005

Aura Science Team Meeting, Den Haag

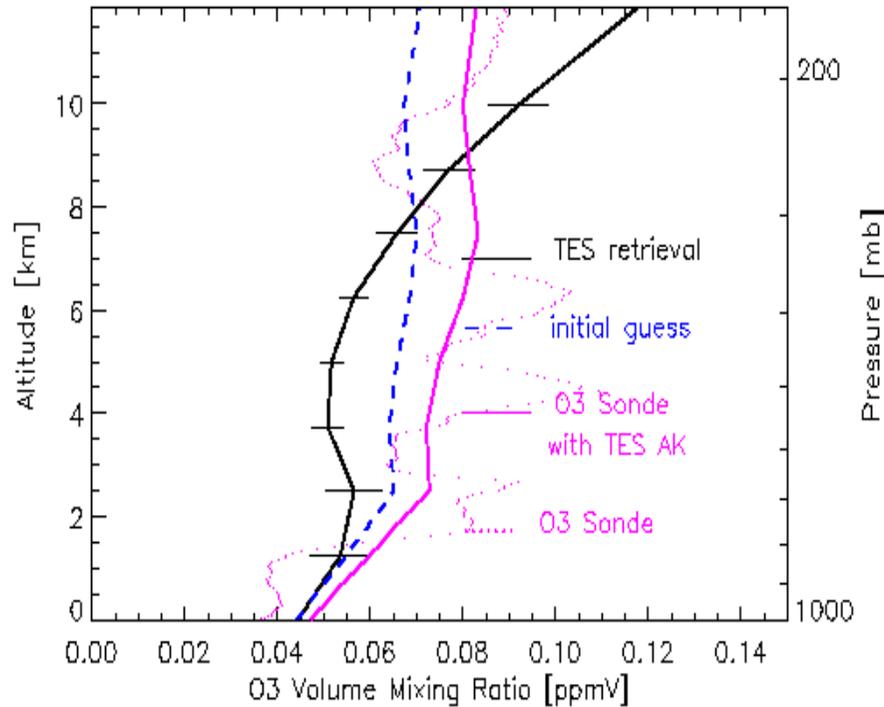
site= Ascension -8N -15E, dist= 354 (km)  
TES UTC= 2004-09-21T02:44 TES-sonde(dec. hrs)= -11.9367



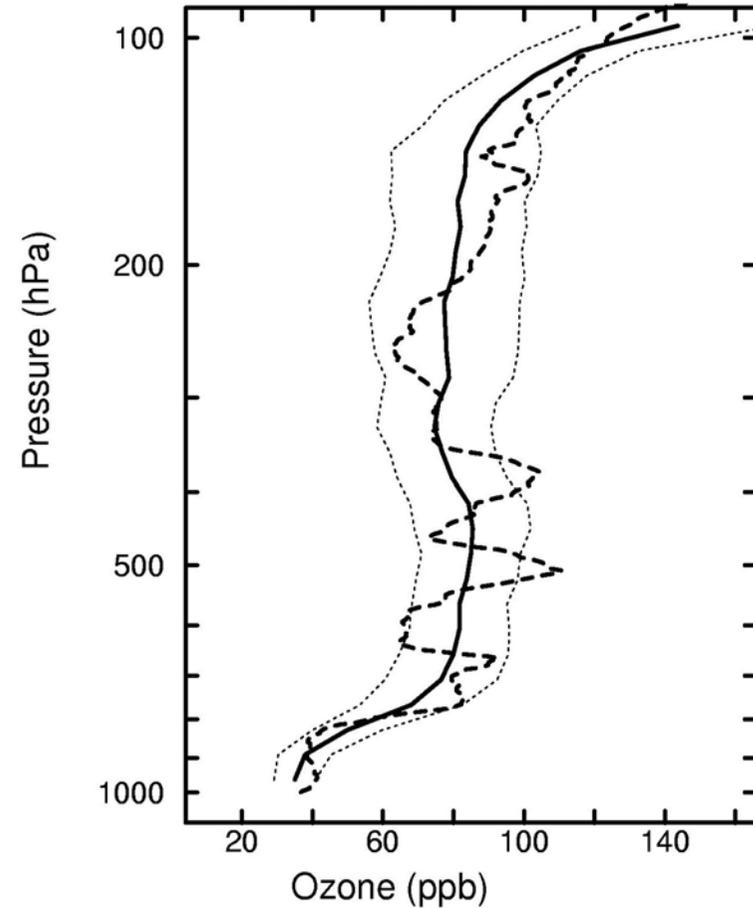
## L1B calfit prototype comparison

H. Worden

site= Ascension -8N -15E, dist= 354 (km)  
 TES UTC= 2004-09-21T02:44 TES-sonde(dec. hrs)= -11.9367



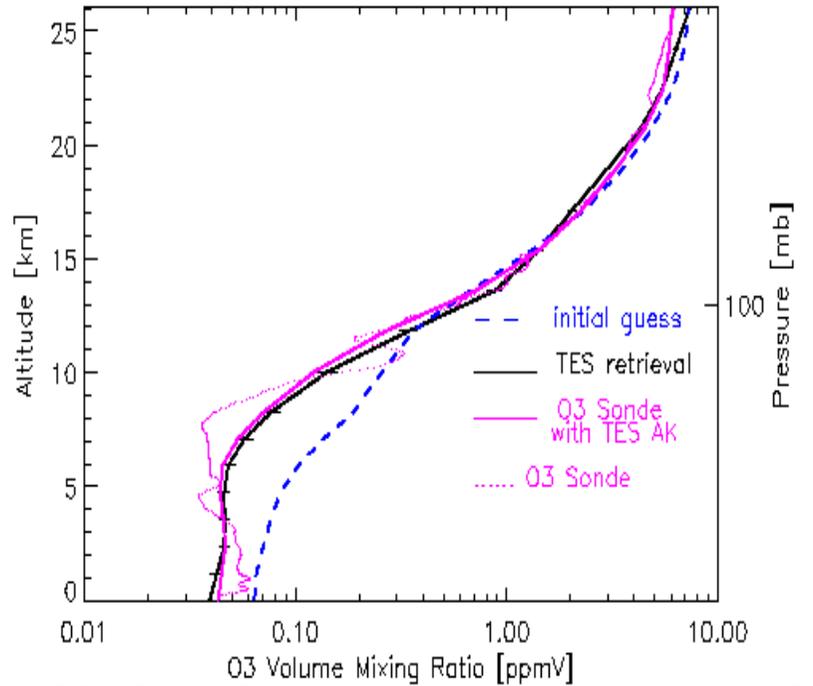
Run2147\_Sea0992\_Scn02 plotted: Thu Oct 13 13:13:42



L1B calfit prototype comparison (troposphere, linear scale)

Ascension O3 sonde data for Sep/Oct 2004

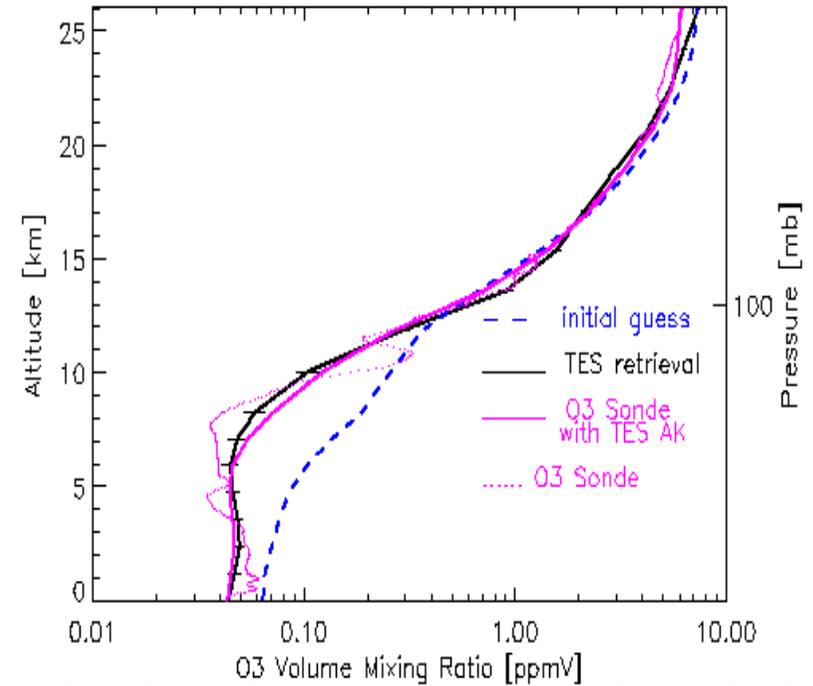
site= Payerne 47N 7E, dist= 339 (km)  
TES UTC= 2004-09-20T12:55 TES-sonde(dec. hrs)= 1.91667



Run2147\_Seq0388\_Scn02

plotted: Mon Jul 11 14:17:!

site= Payerne 47N 7E, dist= 339 (km)  
TES UTC= 2004-09-20T12:55 TES-sonde(dec. hrs)= 1.91667



Run2147\_Seq0388\_Scn02

plotted: Thu Oct 13 11:31:02

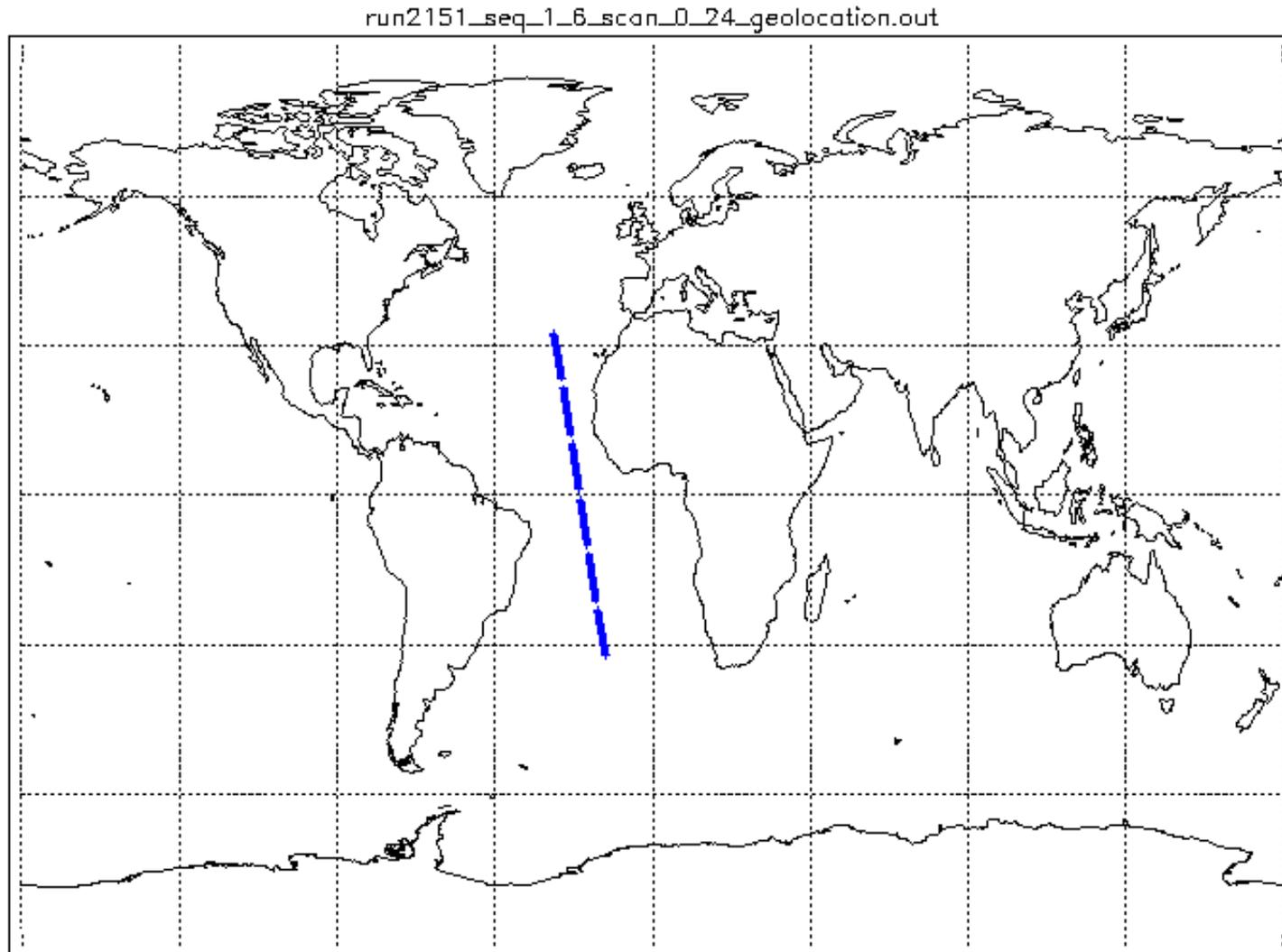
**Sonde comparison  
with current L1B**

**L1B calfit prototype  
comparison**

**Payerne (47° N, 7° E)**

**Note changes to lower O3 in upper trop. & lower strat**

# TES Nadir Step & Stare Observations near Ascension Island



# TES Nadir Step & Stare Observations for 10/31/2004 (AVE)

TES Nadir Step & Stare BT10 (colors = K), Run = 2262, 2004-10-31

